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Experiment and Preliminary Results of Satellite Determinations of the Vertical Distribution of Ozone and of the Albedo in the Near Ultraviolet

3 MAY 1963

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UNITED STATES AIR FORCE
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ABSTRACT

~~This report describes~~ a satellite experiment to determine both the vertical distribution of ozone above 70 km and the radiance of the atmosphere at the center of the Hartley absorption band of ozone at 2550 Å is described. Two flights of the experiment ~~have been~~ were made successfully, resulting in measurement of the vertical distribution between 60 and 85 km and of the radiance at the nadir for sun angles from 90° to about 49°. The vertical distribution data agree with previous results below 70 km and with theory to 85 km. The radiance, which ~~has~~ was not ~~been~~ measured previously, is observed to have a maximum value of ~~2.0×10^{-9} W/cm^2-sr-Å~~ for a solar zenith angle of 49°. W/sq cm-sr-A

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FIGURES

FIGURES (continued)

I. INTRODUCTION

The presence of ozone in the upper atmosphere was proposed first by Hartley to account for the ultraviolet atmospheric cutoff below 3000 Å. This theory was confirmed by Fowler and Strutt [1917], who observed the ozone absorption bands in a stellar spectrum. Later, a mean height of the layer was measured by Cabannes and Dufay [1925], and the vertical distribution was determined by Regener and Regener [1934] and Gotz et al. [1934]. The vertical distribution has since been determined by a variety of methods both from the ground [Karandikor and Ramonathan, 1949; Paetzold, 1955; Venkateswaran, Moore, and Krueger, 1961] and from the use of rockets [Van Allen and Hopfield, 1952; Johnson, Purcell, and Tousey, 1951; Johnson et al., 1952]. By means of rockets, Johnson et al. [1954a] have measured the distribution to 70 km, the highest to date. Theoretical estimates of the vertical distribution by Bates and Nicolet [1950], Craig [1950], and Johnson et al. [1952] predict the distribution to about 90 km. Results of these measurements and theoretical calculations are shown in Figure 1. The characteristics of the geographic and seasonal variations of ozone, however, are poorly understood.

The very strong absorption of ozone within the Hartley band centered at 2550 Å is expected to affect profoundly the earth's albedo within this wavelength interval. Approximate theoretical calculations by Green [1962] have predicted values for the albedo under a number of sun and viewing angles. Experimental determinations are difficult since they must be made from above the atmosphere and either a satellite or a rocket is required. Recently, however, Hennes et al. [1962] have measured the albedo at two wavelengths in the Hartley band, one centered at 2200 Å and the other, at 2600 Å. For the 2600 Å region, the observed reflectivity (albedo) at the nadir was 8×10^{-4}, a measurement which is in approximate agreement with the values predicted by Green [1962]. In the experiments described in this

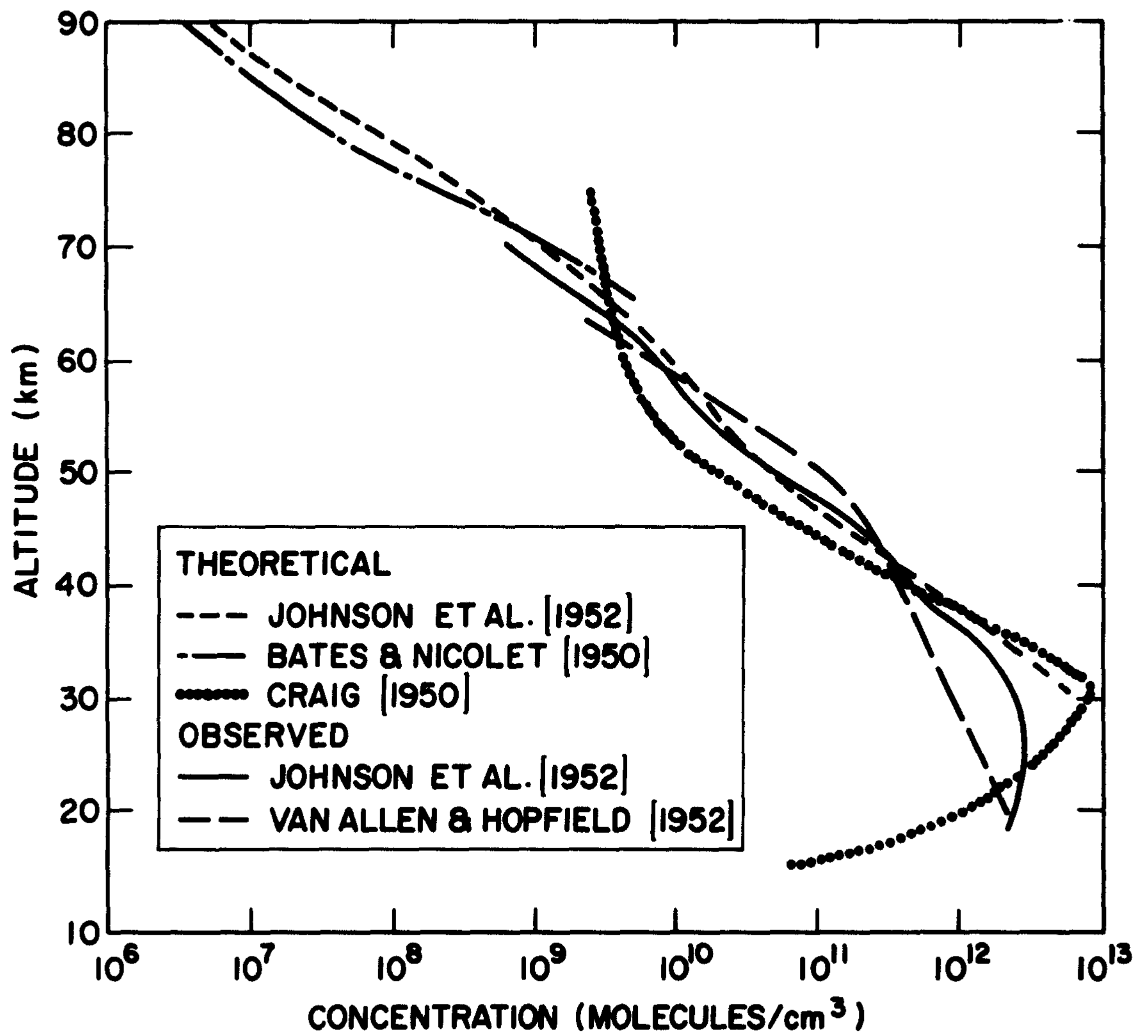

Fig. 1. Theoretical and experimentally observed vertical distribution of atmospheric ozone.

paper, both the albedo and the vertical distribution were measured simultaneously from an orbiting satellite. Two radiometers, with bandpass filters centered at 2550 Å, were used. One observed the radiance of the earth at the nadir; the other observed the irradiance of the direct sun and the transmission of solar radiation through the upper atmosphere as the satellite passed behind the atmosphere and into the earth's shadow. Two experiments were flown on satellites in near-earth circular orbits. This report describes the instruments in detail and presents preliminary data. Subsequent reports will be issued describing the results of the measurements of albedo and the ozone vertical distribution.

II. EXPERIMENT

The experiment was designed to measure at 2550 Å, first, the normal radiance of the atmosphere and, second, the irradiance of the sun and the transmittance of the upper atmosphere as a function of altitude. From the latter, the vertical distribution of ozone can be calculated. The measurements were made with two filter radiometers, one designed to look at the atmosphere at the nadir and the other, to look at the sun during sunrise and sunset when the solar radiation is being attenuated by the upper-atmospheric ozone. Both radiometers used similar filters and photomultipliers and were mounted in the same box. Figure 2 is a sectional drawing of the instrument showing the two radiometers. Each instrument consisted of collecting optics, composite filter, solar blind photomultiplier tube, calibration lamp, and electronics. A photograph of the two radiometers is shown in Figure 3.

A. Optics

The albedo channel used a simple 1 in. diameter, 1.5 in. focal length quartz lens with a 0.015-in. field stop to limit the field of view to 10 mrad or to a 2-mi circle on the ground when the satellite was at an altitude of 200 mi. The solar channel was designed to sample the solar irradiance uniformly. It used a hemispherical boss ground into the end of a quartz rod to scatter a fraction of the solar radiation toward the photomultiplier. This sampling was completely independent of the solar azimuth angle, and it was constant within a few percent for solar elevation angles within the 20° range of possible measurement.

B. Spectral Characteristics

The requirements on the filter were very severe due to the variation in the absorption coefficient of ozone, from about 120 cm^{-1} (base 10) near 2550 Å down to about 10 cm^{-1} near 3000 Å. The filter would, of necessity, transmit over a band of wavelengths and also have a finite, though small,

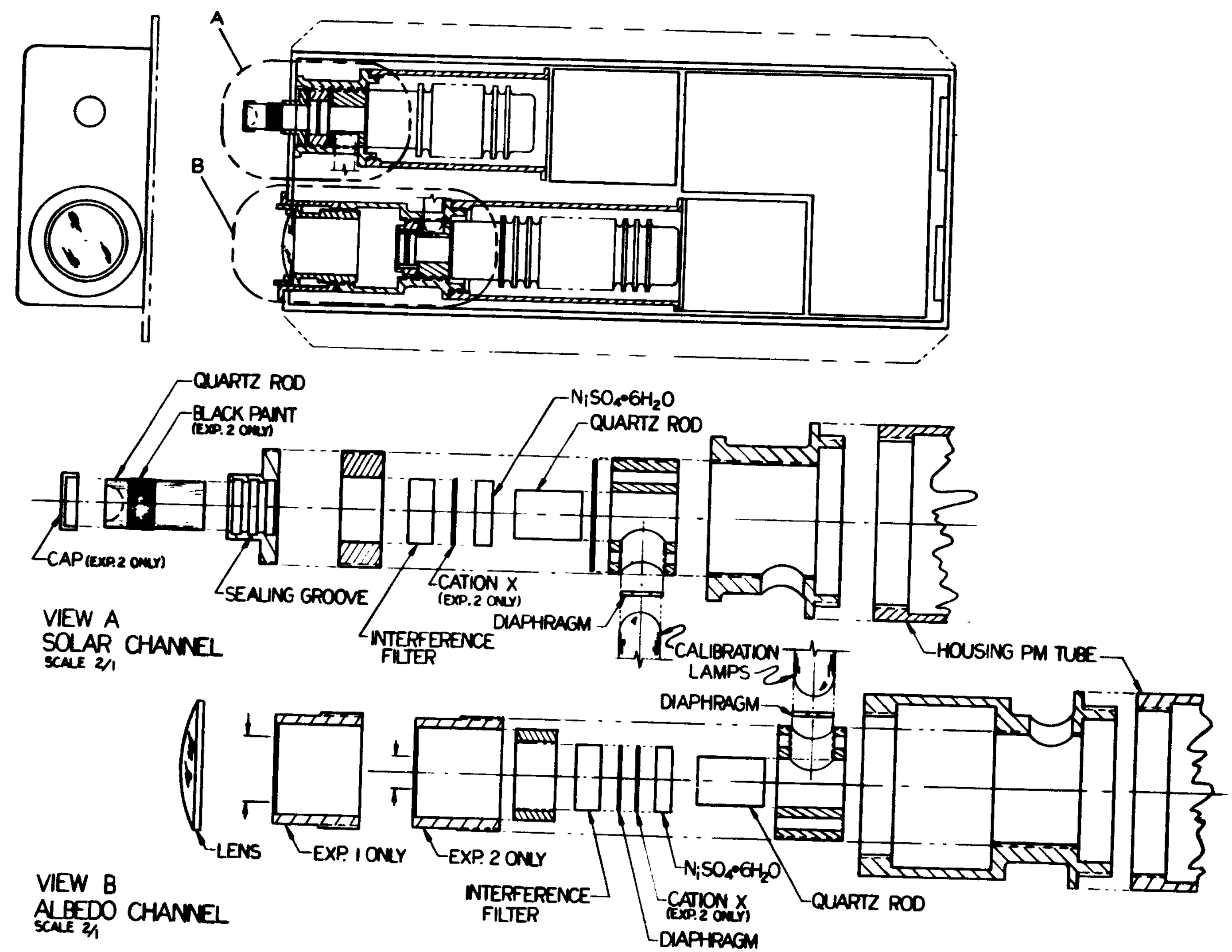

Fig. 2. Detail of radiometers showing filter and diaphragm positions for both experiments.

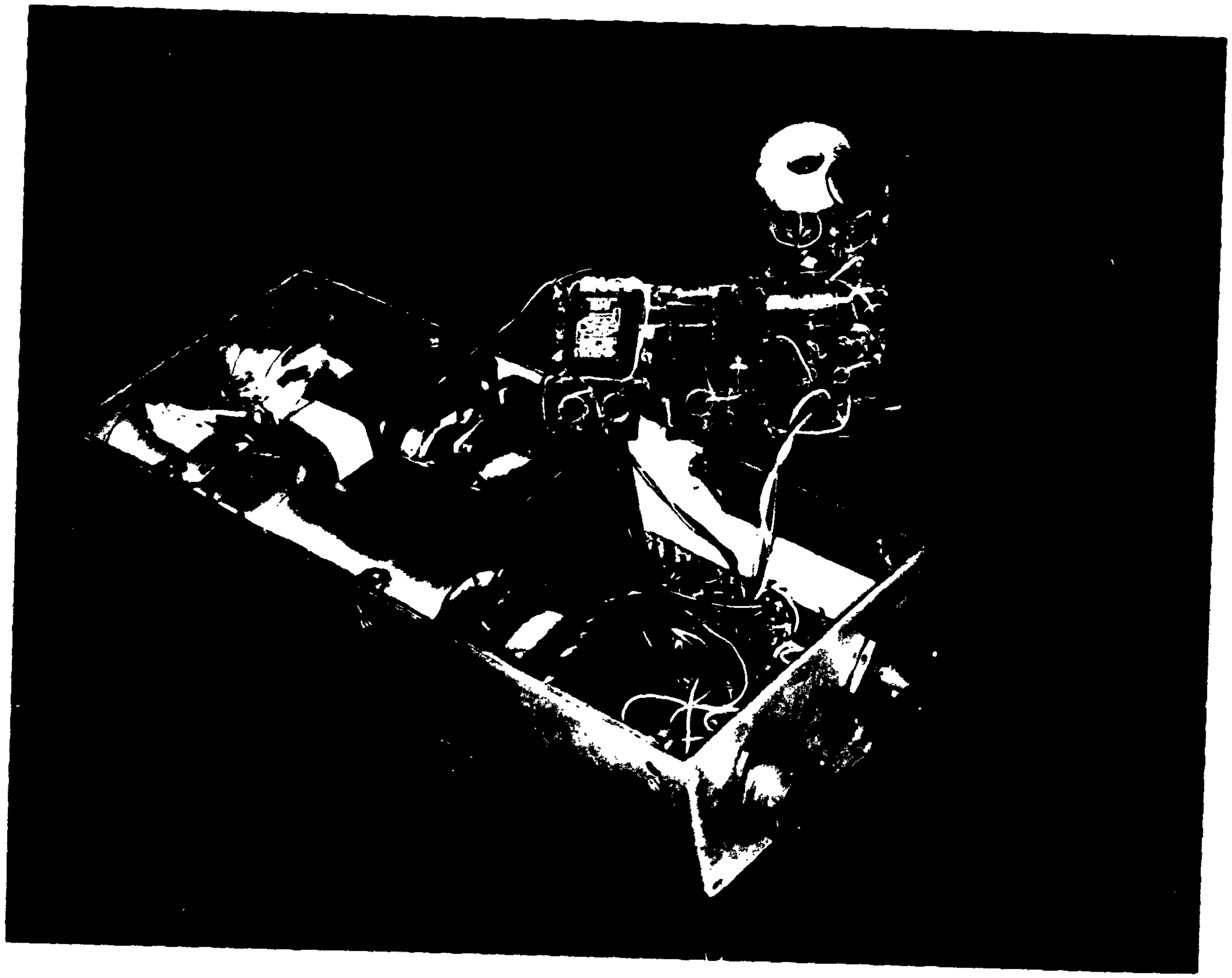

Fig. 3. Solar and albedo radiometers showing high-voltage power supplies and amplifiers.

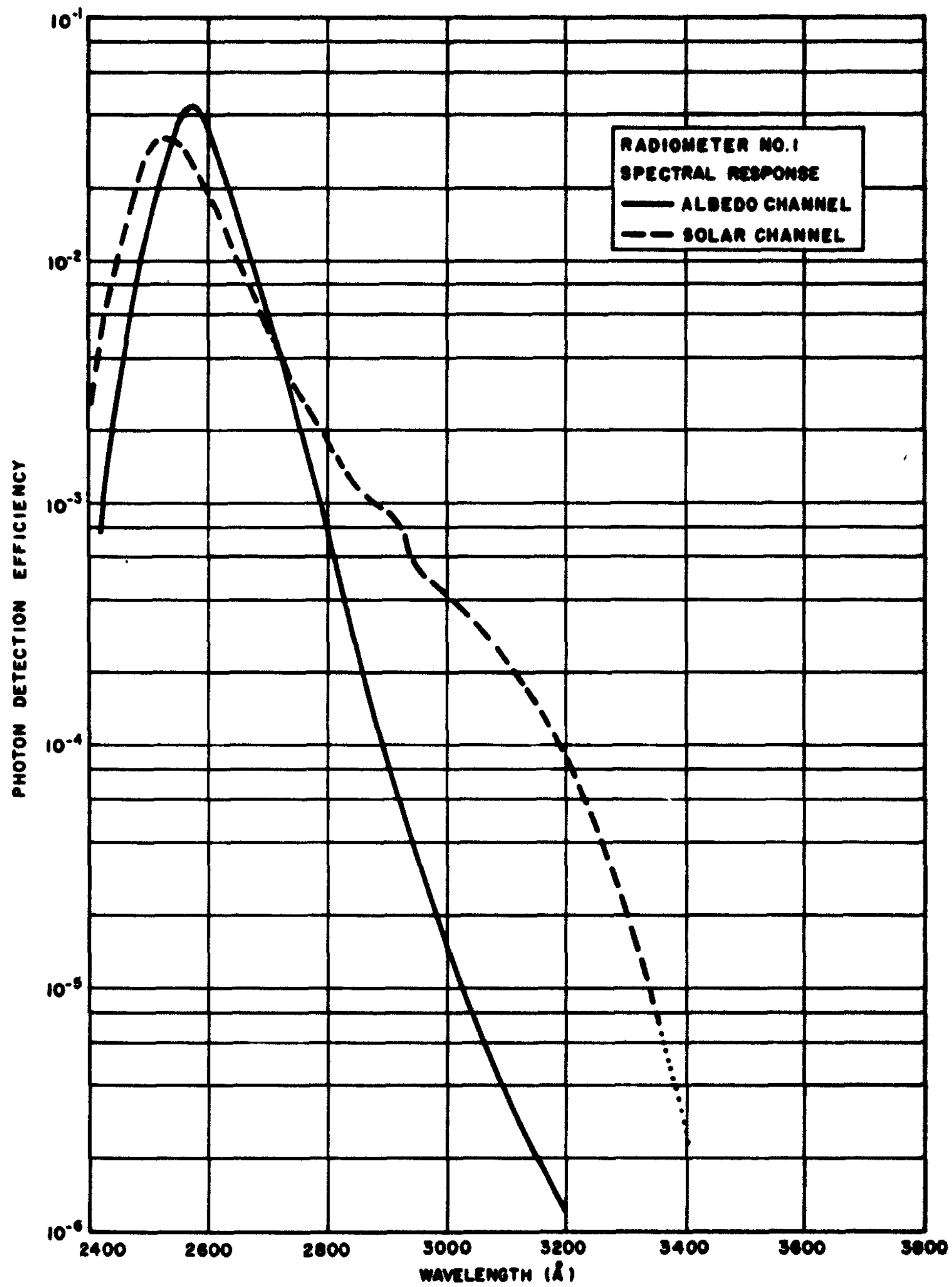

Fig. 4. Spectral response of the radiometer flown in Experiment 1.

transmittance in the "tails" of its curve. The over-all radiometer spectral sensitivity is given by the product of the filter transmittance curve and the detoctor sensitivity curve. This sensitivity in the long wavelength tail of the curve must be manyfold smaller than it is near the peak if the strong incident radiation in the 3000 to 4000 Å region is not to overwhelm that in the desired interval. No completely satisfactory filter is achievable by current techniques. The filter used in the first experiment had an appreciable leak in the 3000 to 3400 Å region. In the second experiment, this leak was corrected partially by an additional component (Cation X) in the filter system.

The filters used for the first experiment were a combination of an interference filter used in the third order and a layer of nickel sulphate hexahydrate, $NiSO_4$, $6H_2O$, 0.125 in. thick. Nickel sulphate, which absorbs strongly between 3400 and 4300 Å, was used to suppress the second-order transmission of the interference filter. For wavelengths longer than 4300 Å, the quantum efficiency of the photomultiplier is sufficiently low to suppress the first-order transmission. From the first experiment, the spectral response of the filters and the photomultipliers combined is shown in Figure 4. Maximum transmission occurred at 2580 Å and 2530 Å for the albedo and vertical distribution radiometers, respectively. The differences in wavelength at peak sensitivity and in the over-all shape of the transmission curves were due to variations in the interference filters and phototube response.

As shown by Figure 4, the sensitivity at 3000 Å was lower than that at the peak wavelength by three orders of magnitude for the albedo channel and two orders of magnitude for the solar channel. These differences in sensitivity were not sufficient to eliminate the relatively strong radiation at the longer wavelengths. A rough calculation of the possible effect of this leakage in the albedo channel is given in Appendix A.

In addition to the above described leakage, there may have been another form of light leakage in the first radiometer. The aperture stop was a disc mounted between the interference filter and the nickel sulphate. If light

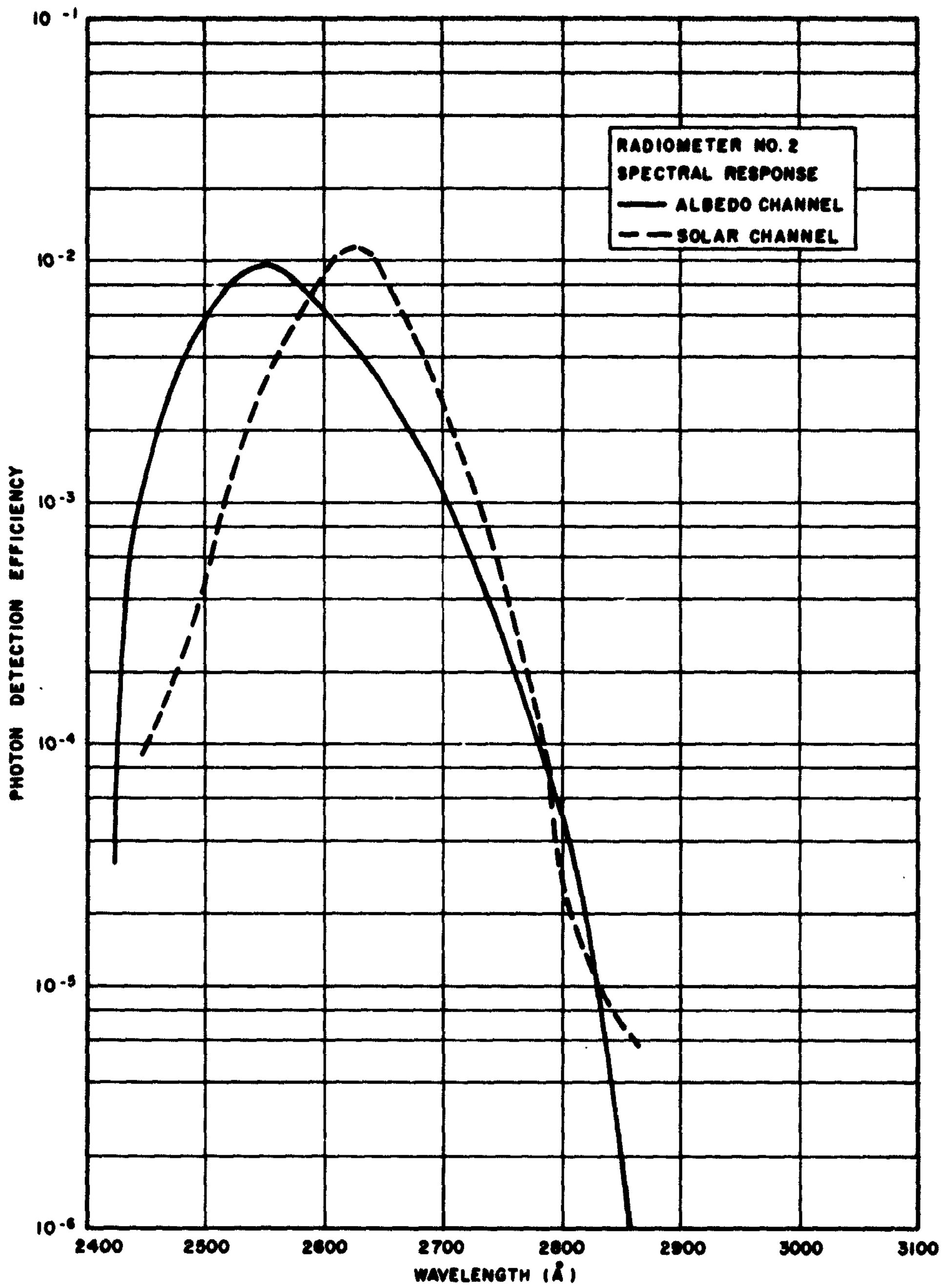

Fig. 5. Spectral response of the radiometer flown in Experiment 2.

came in at a large angle, it may have been able to pass through the interference filter and then around the edge of the aperture disc, thus missing the nickel sulphate. This possibility was suspected upon examination of the data from the experiments. A test was made on a radiometer with components arranged as nearly identical as possible to those in the flight units. (The test is discussed in Appendix B.) Although the test showed that this leakage could have been significant, the results were inconclusive, because there was no way to duplicate precisely the flight radiometer and conditions it was subjected to during launch.

In the second radiometer experiment, a third filter component was added to further suppress the transmission in the 2900 to 3400 Å region. This filter was Cation-X (2, 7 dimethyl-3, 6 diazocyclohepta-1, 6 diene perchlorate) in a polyvinyl alcohol film.* Spectral response curves for the composite filters and the photomultipliers are shown in Figure 5. As well as the addition of the Cation-X filter, a modification of the filter holder was made to prevent rim leaks. It is felt that this filter system was adequate for the albedo channel. No available filter, however, is completely satisfactory for the solar channel due to the large ozone absorption encountered which enhances the relative contribution at long wavelengths as the attenuation increases.

C. Electronic Circuitry

Each radiometer contained a high-voltage power supply, a calibrating lamp, timing control and power supply for the calibrating lamp, and two nonlinear amplifiers to compress a dynamic range of about 10^3 in the input signal into two output analog voltage ranges of 0 to 5 V each for the satellite telemetry.

*Supplied by Dr. William McBride, Research Department, U. S. Naval Ordnance Test Station, China Lake, Calif.

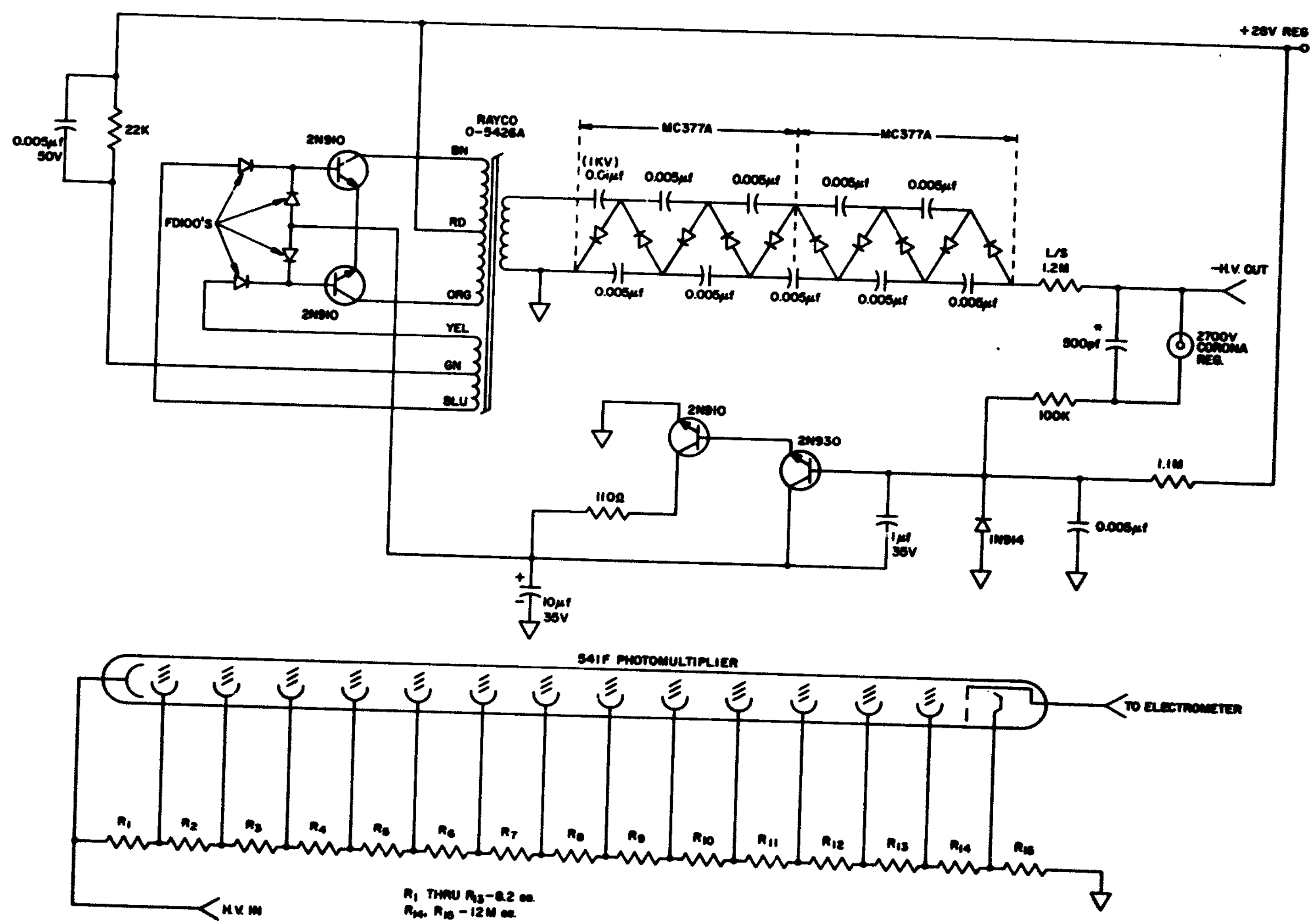

Fig. 6. Wiring diagram for the power supply used in both experiments.

The high-voltage power supplies employed voltage multiplication and a glow discharge tube for regulation. The glow discharge tubes used were Victoreen Corotron voltage regulators Type GV3A. The volt-ampere characteristics of these tubes permit operation from 16 to 500 μA. They are temperature stable to about two percent from -65°C to +125°C and have a regulation of about 85 V over the full range. Additional regulation was provided through feedback control of the power supply oscillator voltage. Regulation of the output high voltage over the temperature range used for flight qualification was very good; ripple and noise were negligible. The power supply circuit diagram for the albedo radiometer is shown in Figure 6. The same supply was used for the solar radiometer except that the output voltage was -1400 V dc.

The calibration lamps used in flight as a check on the laboratory calibration were argon-filled arc discharge lamps manufactured by the Ultra-Violet Corporation of San Gabriel, California, under the name Pen-Ray Lamp. After aging for three weeks, the lamps produced a stable output flux in the ultraviolet which was reproducible to within a few percent. Circuitry for the calibration lamps, including timing, switching, and power supply, is given in Figure 7. With this circuit, a 10-sec calibration pulse was supplied alternately each 2 min to the albedo and solar lamps so that a calibration pulse occurred each 4 min on a radiometer. The flux from the lamps was adjusted by means of a diaphragm so that the calibration of each radiometer was monitored near the middle of its dynamic range. In this manner, both the upper and lower ranges which overlapped near the middle of the range were checked.

Amplification of the photomultiplier anode current and compression of the dynamic range of 1000 in current into two 0 to 5 V outputs for the satellite telemetry was accomplished in a two-range amplifier. This reduced the compression since each range of the amplifier was independently telemetered, and each range covered half of the entire dynamic range.

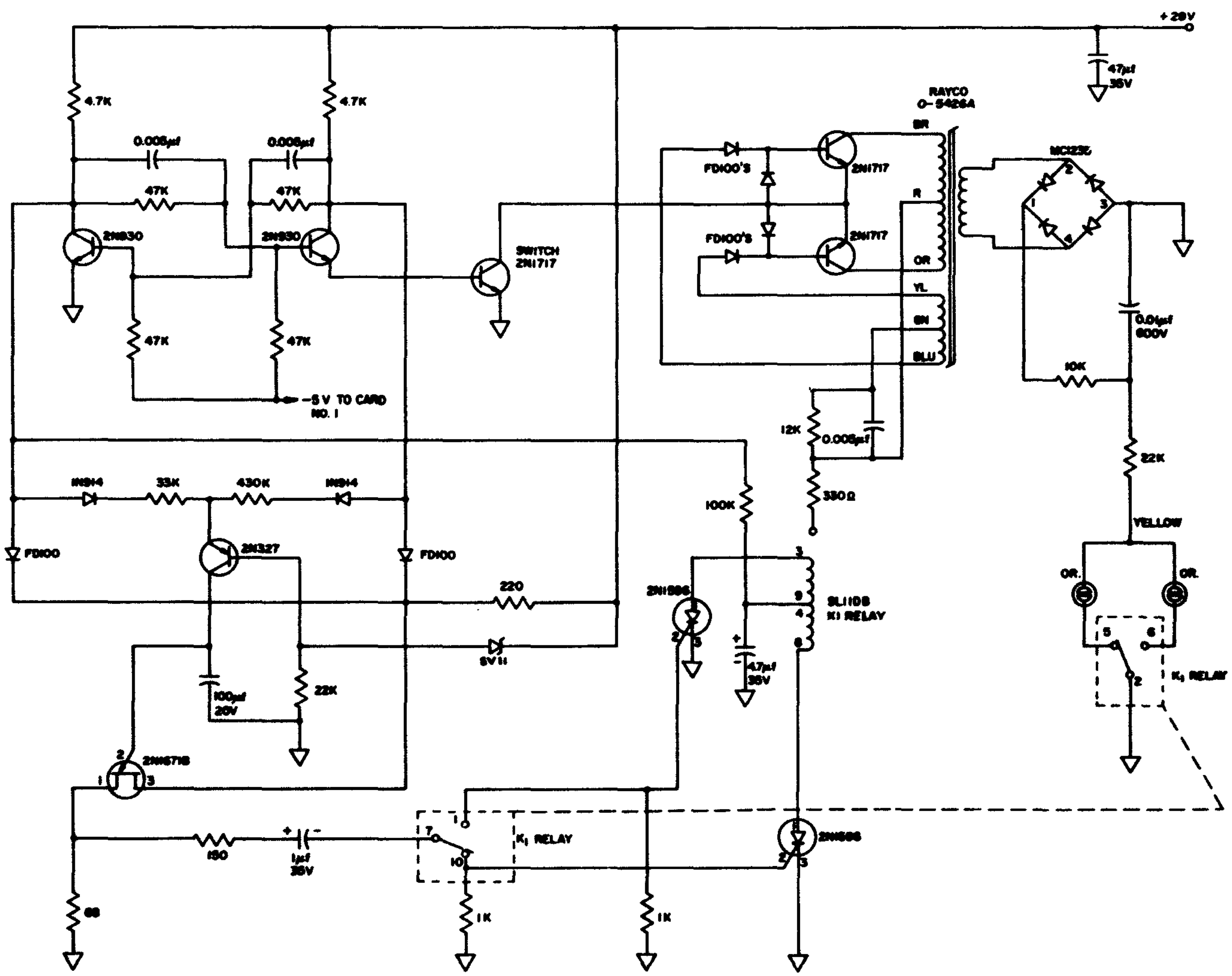

Fig. 7. Wiring diagram for the control circuit for the calibration lamp.

The amplifier circuit employed is shown in Figure 8. Anode current from the photomultiplier was integrated in a capacitor and discharged through a relaxation oscillator. If the current was large, the average current was read. If the current was small, individual pulse discharges could be counted. This gave a wide dynamic range in the laboratory. Unfortunately, it was not entirely satisfactory in a satellite. The telemetry sampling rate bore no relationship to the discharge rate, so the pulses appeared to come at random. The net effect was that this pulsing superposed about 0.3 V noise on the signal at the low end of the range, limiting the observations at low radiance values to magnitude only and precluding accurate determination of radiance differences.

The gain of the amplifiers changed with temperature so that it was necessary to telemeter the temperature during flight. This was done using two thermistors which were located at the base of the albedo photomultiplier tube. One thermistor covered the range from $-18^{\circ}C$ to $+26^{\circ}C$, and the other covered the range from $+16^{\circ}C$ to $+40^{\circ}C$. Both thermistors were recorded every 2.5 sec and transmitted with the radiance data. Prior knowledge of typical temperatures encountered during flight indicated that operation would be well within these limits. In the first experiment, unfortunately, the thermistors were not connected at the time the radiometers were installed in the satellite, and no thermistor data were obtained. However, the amplitude of the calibration lamp pulse was also temperature dependent. From data obtained during temperature cycling of the box in the laboratory, it was deduced that the temperature in orbit was about $5^{\circ}C$. The second experiment obtained temperature data, however, which indicated that the variations were from $+6^{\circ}$ to $+15^{\circ}C$ with the average about $+10^{\circ}C$.

D. Calibration

Absolute calibration of the radiometers was made using a National Bureau of Standards spectrally calibrated lamp. The spectral radiance of the lamp was certified to a lower wavelength limit of 2500 Å at 100 Å intervals. At 2500 Å, however, the radiant intensity was so low that only

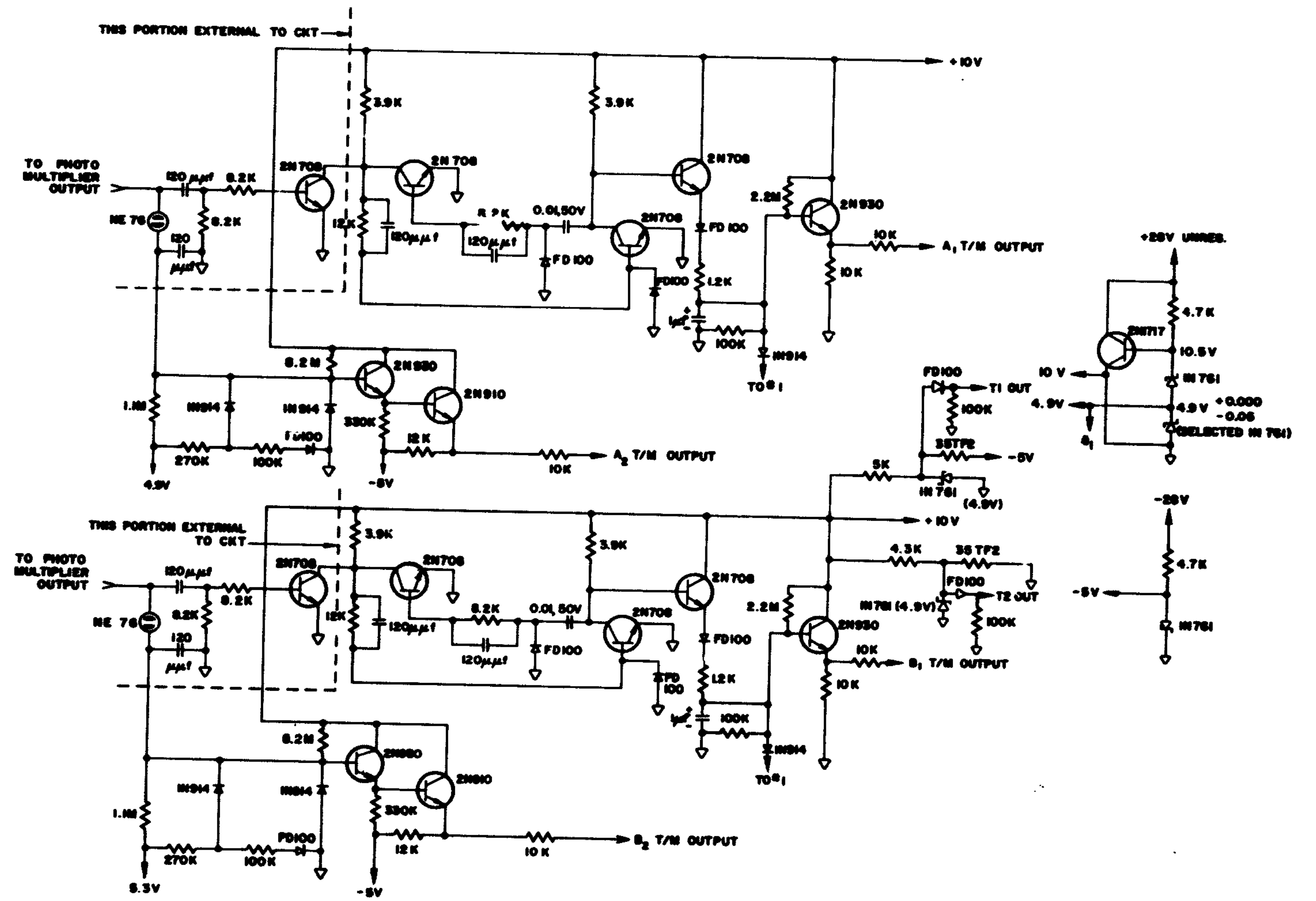

Fig. 8. Wiring diagram for the nonlinear amplifiers.

the albedo channel could be calibrated directly. For the solar radiometer it was necessary to use a mercury vapor lamp as a secondary standard.

First, the response of the albedo channel to the NBS lamp was determined for the widest possible range of distances between the lamp and the radiometer. Then, the mercury lamp was substituted and placed so as to produce a radiometer response which overlapped that from the NBS lamp. From a number of such readings, and the use of the inverse square law, the ratio of the effective radiant intensities of the two lamps was calculated.

Since the amplifiers for both radiometers were affected by temperature changes, it was necessary to calibrate at a number of temperatures from $0^{\circ}C$ to $+40^{\circ}C$. This was done in a controlled oven, the instrument being allowed to come to equilibrium at each setting before calibration. Calibration curves for both radiometers at room temperature are shown in Figures 9a and 9b for the first experiment and in Figures 10a and 10b for the second experiment. The ordinate is the output voltage to the telemetry. The abscissa for the albedo radiometer is in units of spectral radiance (W/cm^2-sr-Å). The abscissa for the solar radiometer is in units of spectral irradiance (W/cm^2-Å).

To calibrate the radiometers it was necessary to know the average flux that each would observe. For the solar irradiance the data of Johnson [1954a; 1961] were used. For the background radiance, however, no experimental data were available, and only calculations based on Rayleigh scattering were known. The expected radiance based on the calculations was approximately 10^{-9} W/cm^2-sr-Å in the 2500 Å region. This value was used as the midpoint of the low range for the radiometer.

In the first experiment, the measured response of the albedo channel was high enough to be well above noise. However, this radiometer had the filter leak. In the second experiment, the filter leak was corrected. However, the Cation-X component absorbed so much radiation that the amplifier was in the pulse-counting region and a noisy readout was produced.

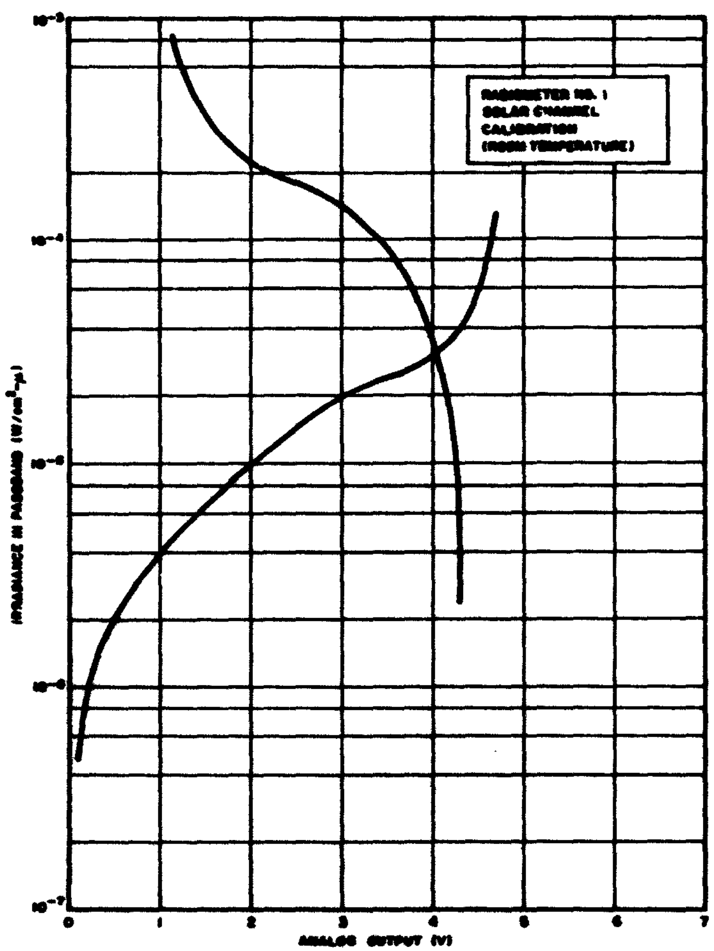

Fig. 9a. Calibration curve for the solar radiometer at room temperature for Experiment 1.

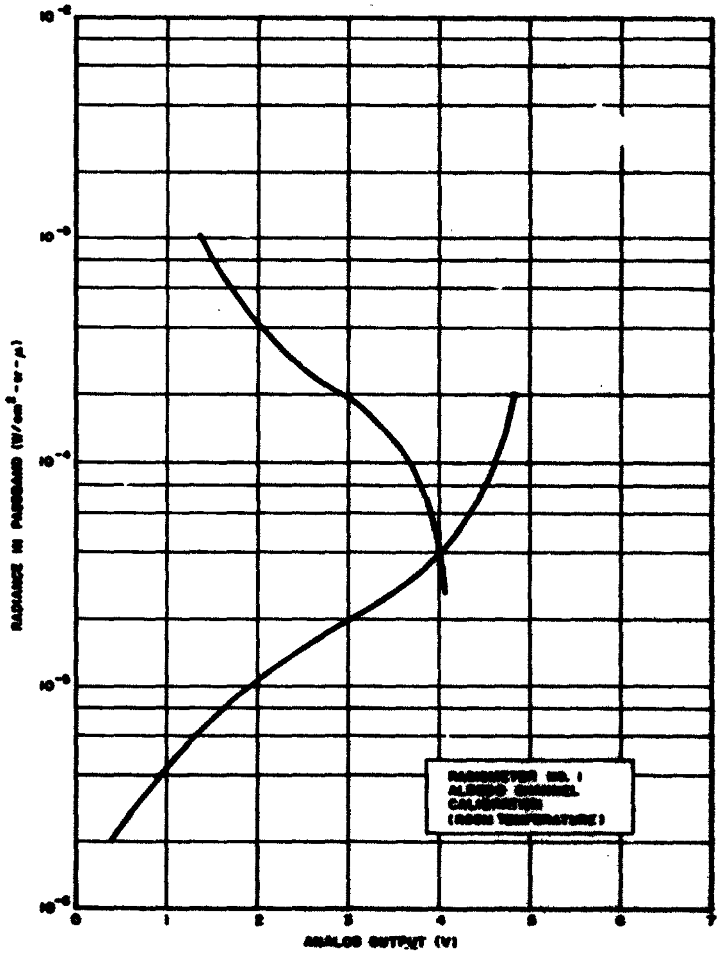

Fig. 9b. Calibration curve for the albedo radiometer at room temperature for Experiment 1.

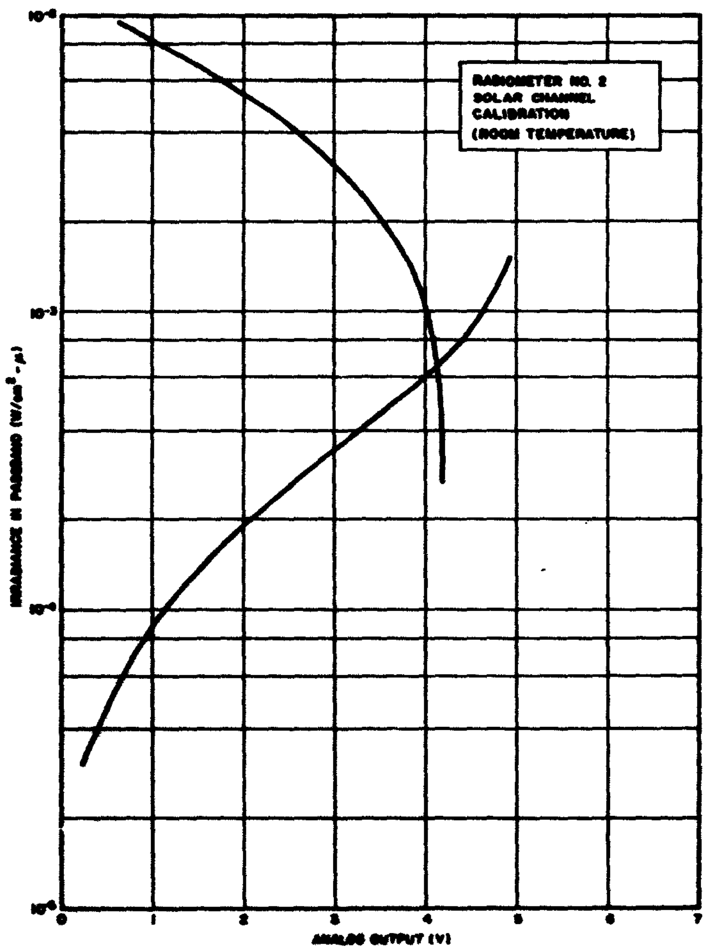

Fig. 10a. Calibration curve for the solar radiometer at room temperature for Experiment 2.

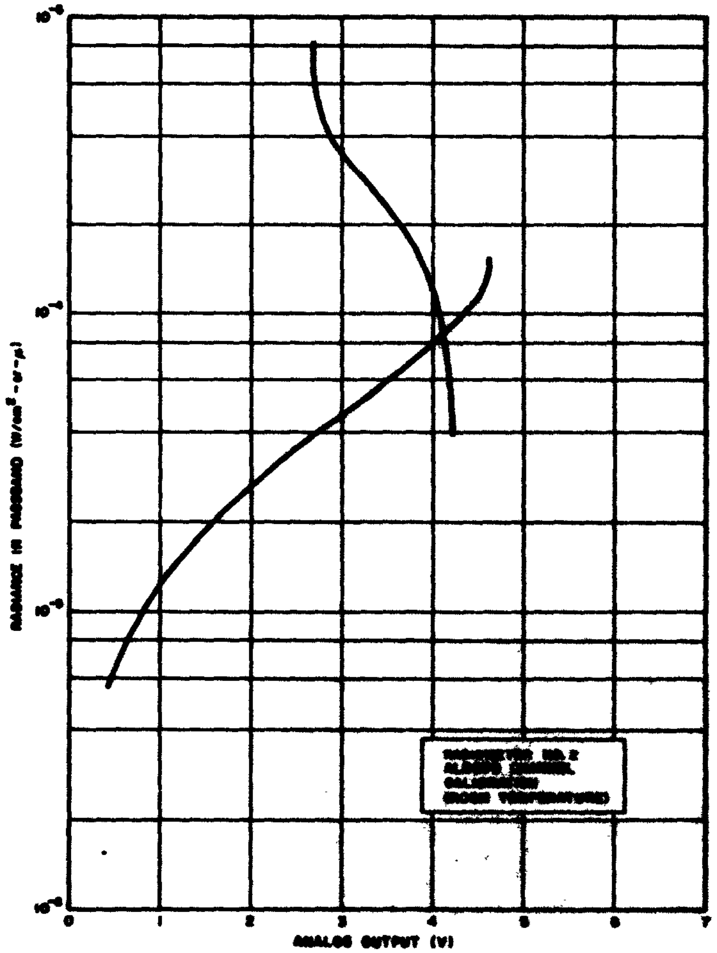

Fig. 10b. Calibration curve for the albedo radiometer at room temperature for Experiment 2.

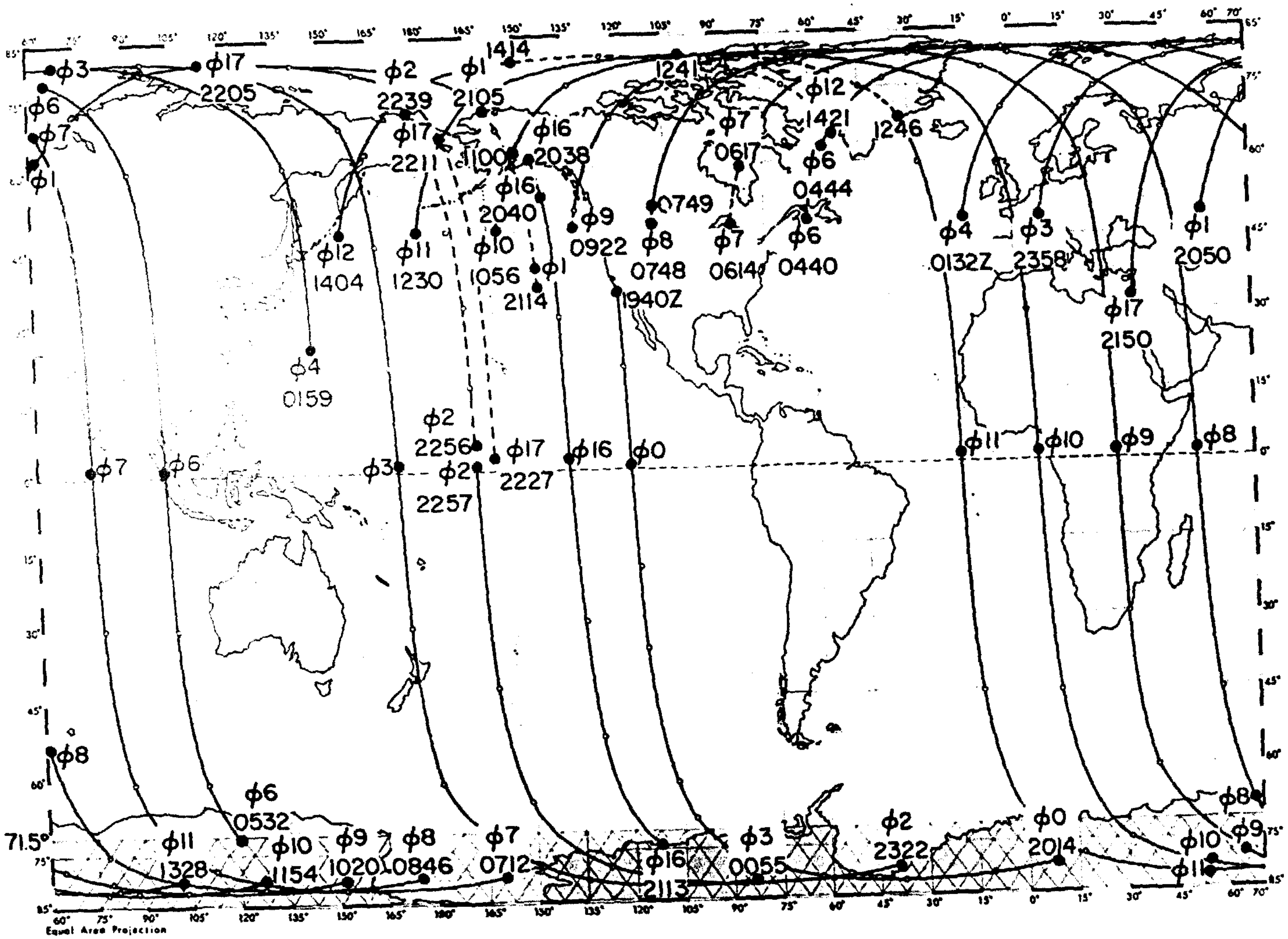

Fig. 11. Trace of the orbits for which data were obtained for Experiment 1.

E. Results

The first experiment was launched in mid-May from Vandenberg Air Force Base. Orbit inclination was 82.3°, perigee 298 km, and apogee 650 km. The period was 94.026 min. Both radiometers functioned properly, and realtime and tape data were obtained for 17 orbits. After 17 orbits the telemetry failed and no further data were obtained. Of the 17 orbits recorded, nine were useful for analysis. The remainder were excessively noisy or missing due to telemetry dropout. In addition, 17 realtime acquisitions were made from which six occurred as the satellite crossed the terminator and gave vertical distribution data.

Figure 11 shows a trace of the orbits for daylight passes and indicates realtime data as well as crossings of the terminator which occurred at a south latitude of 71.5°. Typical tape recorded data from the first experiment for both radiometers are shown in Figures 12a and 12b. These figures are plots of the commutator voltages read from the tape and are compressed in time by a 26.1-to-1 factor which was the playback speed of the flight tape recorder. Before solar irradiance or background radiance could be determined, the data had to be converted from voltage using the correct calibration curve. Since the calibration curves are nonlinear, it was difficult to make accurate inferences about the time-intensity characteristics from the telemetered voltage. Generally, the vertical distribution signal was as expected, a smooth transition from full to zero signal to full signal. The background radiance signal, however, was not as expected since the maximum value observed was about two orders of magnitude greater than predicted and showed evidence of significant structure.

The unexpectedly large value for the peak background radiance is believed due to the filter leaks discussed earlier.

The second experiment was launched in late July from Vandenberg Air Force Base. Orbit inclination was 70.3°, perigee 205 km, and apogee 393 km. The period was 90.431 min. Again both radiometers functioned

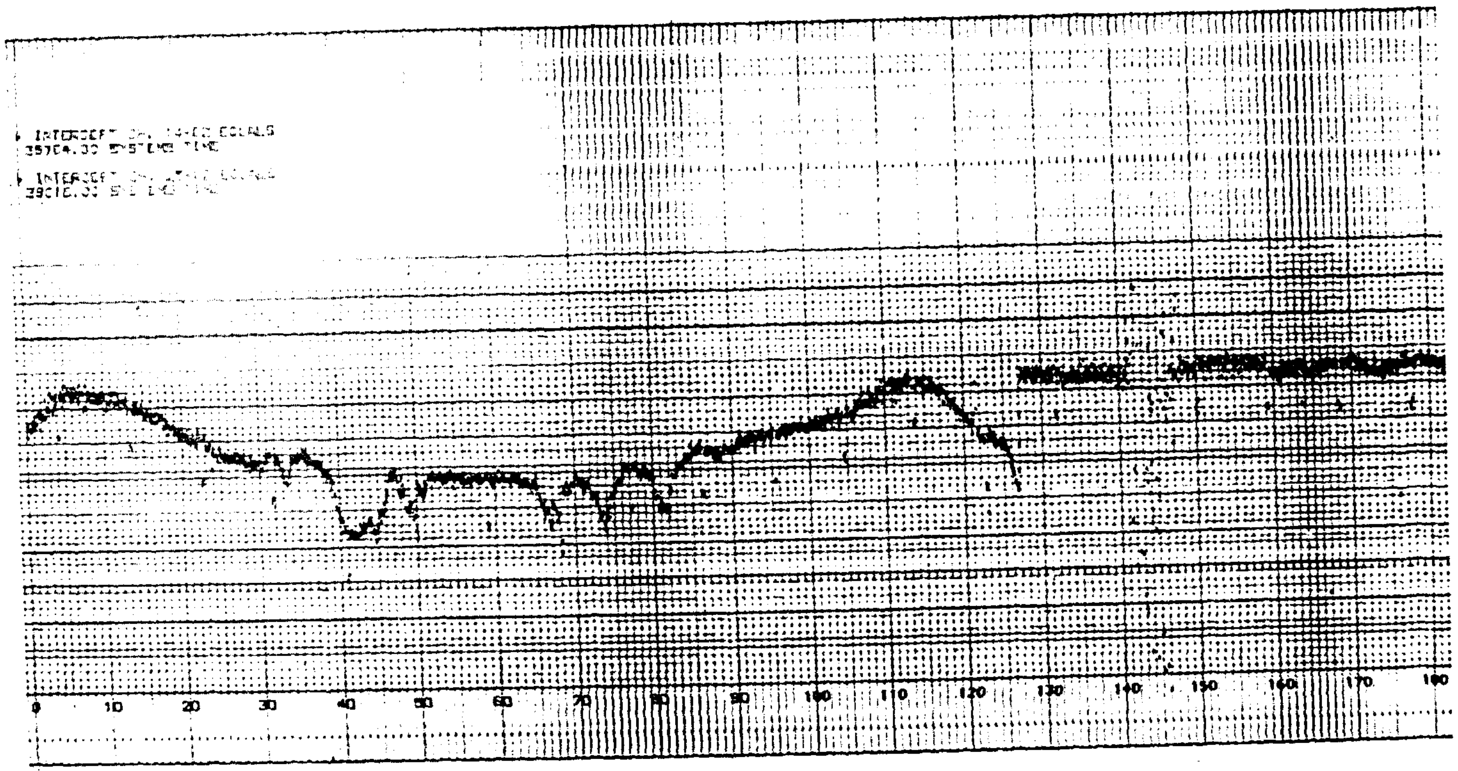

Fig. 12a. Tape data for one complete orbit of the albedo radiometer for Experiment 1.

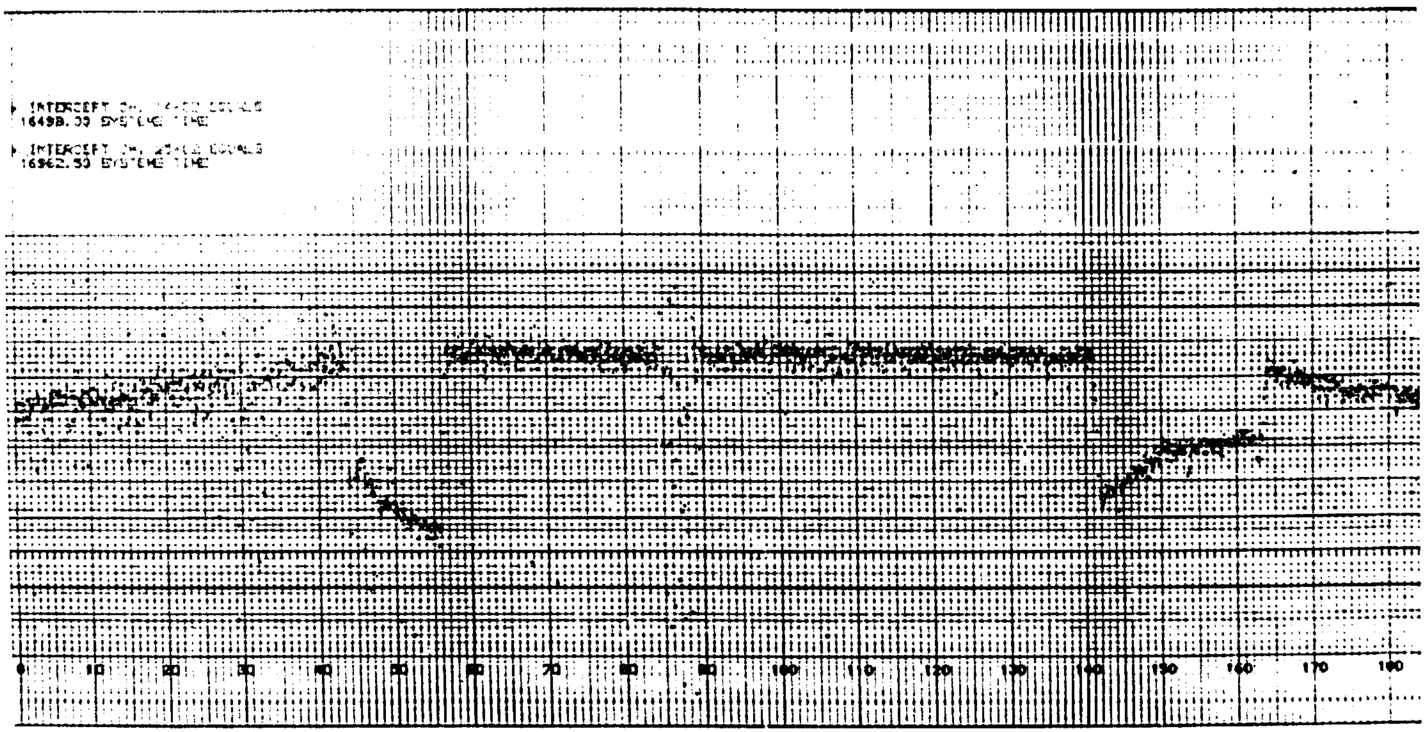

Fig. 12b. Tape data for one complete orbit of the solar radiometer for Experiment 1.

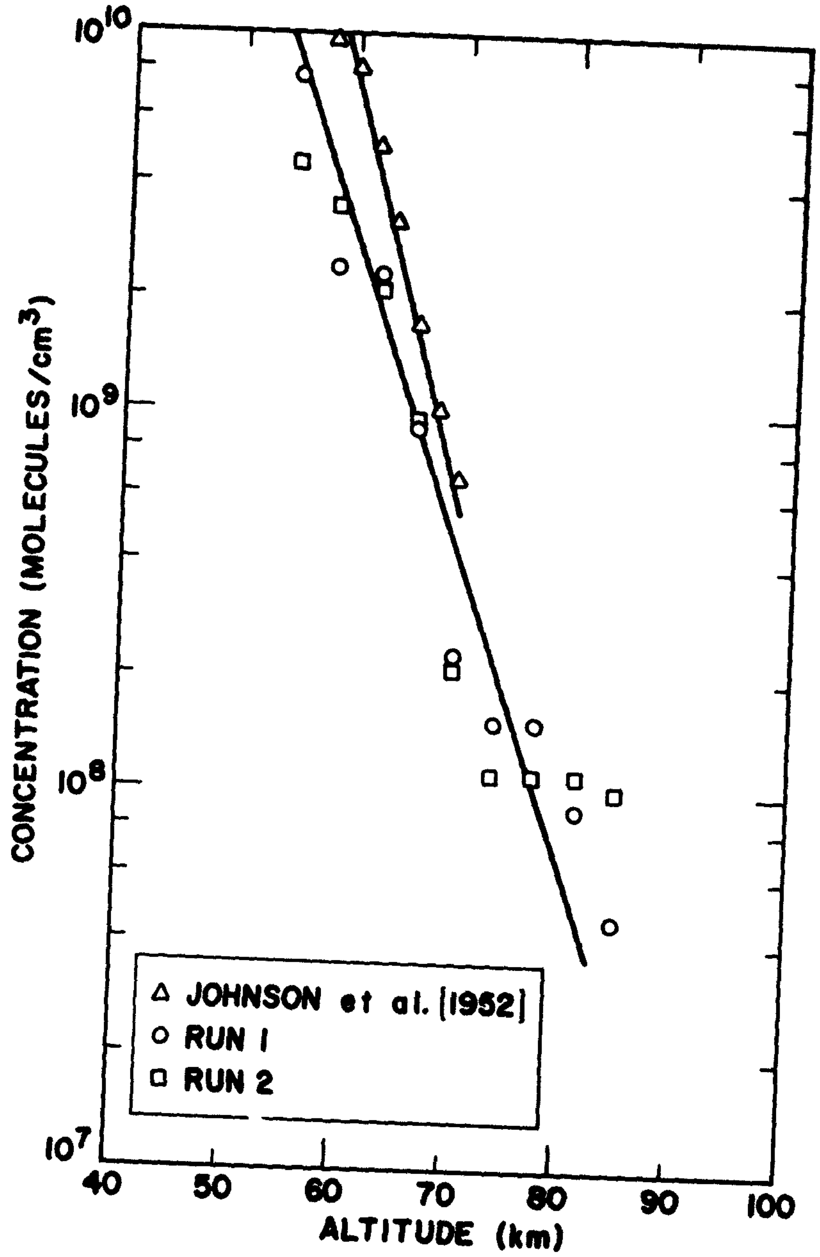

Fig. 13. Experimentally determined vertical distribution of ozone to 85 km compared with the probe data of Johnson et al. [1952].

properly; realtime and tape data were obtained for the albedo radiometer, and tape data were obtained for the vertical distribution radiometer for 107 orbits. After 94 orbits the satellite lost stability and tumbled. It was hoped that albedo data would be obtained for aspect angles other than the nadir. Unfortunately, the telemetry on the flight was excessively noisy, and most of the data were unusable. No orbits beyond number 54 were reducible from the telemetered wave train. A total of six orbits of data were reduced from tape recordings, and 23 realtime acquisitions were obtained for the albedo radiometer.

For the vertical distribution radiometer, 50 crossings of the terminator were reduced from tape recordings. The clock on the satellite failed, however, so that the precise timing required for the ozone calculation was not available. Hence, this analysis could be done only by artificially generating a time base, and even this was possible for only one playback record containing several orbits of data. Results shown in Figure 13 are compared with those of Johnson, et al [1952]. Despite the uncertainties in unfolding the data, agreement is satisfactory.

Figure 14 shows a trace of the orbits for the daylight passes for which data were obtained. Typical tape recorder data for both radiometers are shown in Figures 15a and 15b. In this experiment, the maximum value for the background radiance observed was about 2×10^{-9} W/cm^2-sr-Å for a sun-zenith angle of 49°. However, because of telemetry noise and the pulse output of the amplifier at the bottom of its lower range, it was not possible to determine radiance differences from the data. As before, the vertical distribution radiometer data were as expected.

F. Discussion

The results obtained indicate that the methods are satisfactory. Some difficulty still exists in the ultraviolet region below 3000 Å, however, due to the lack of adequate filter materials. Considerable care must be taken to ensure that the system is mechanically secure and free of leaks. A

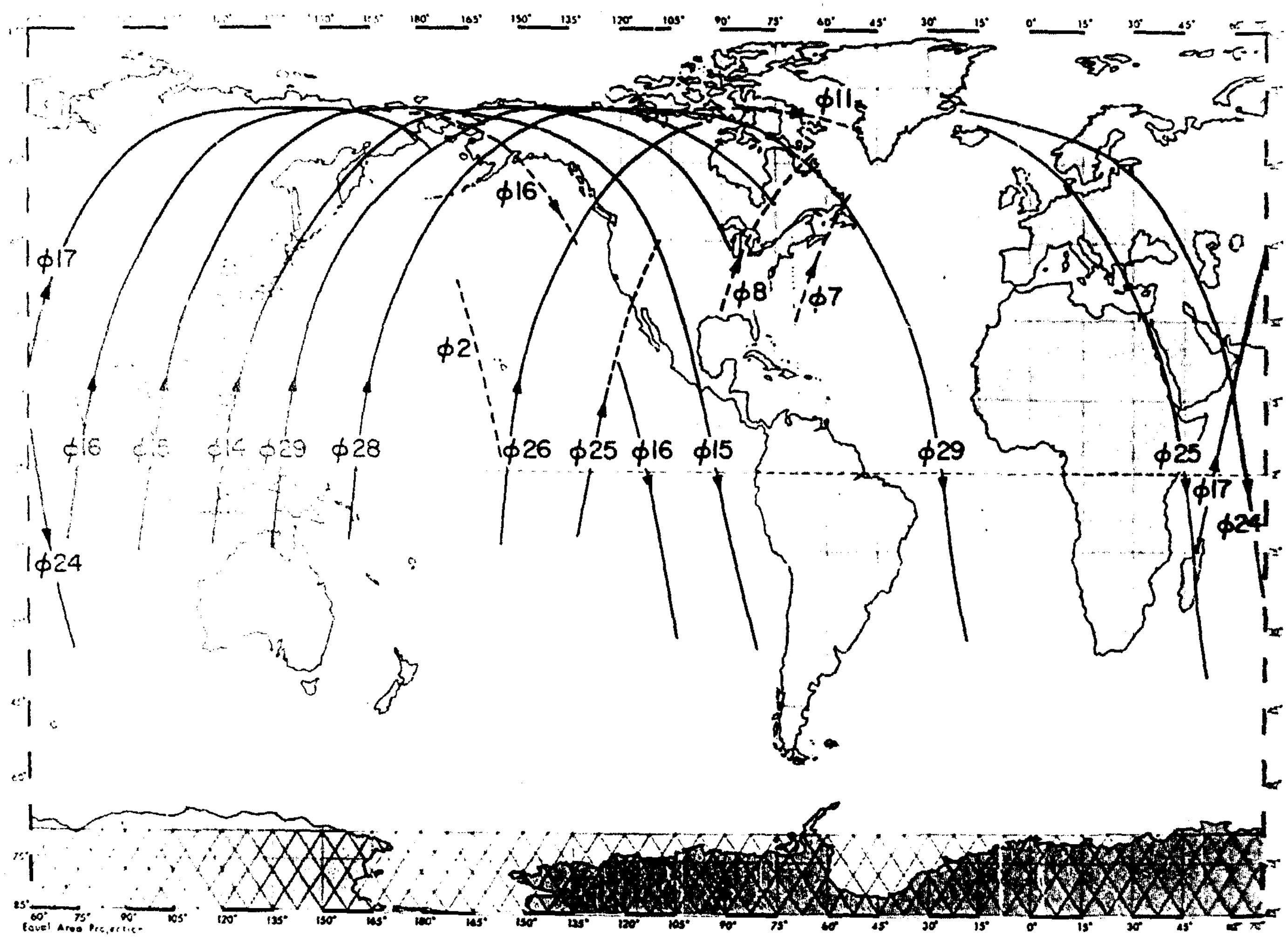

Fig. 14. Trace of the orbits for which data were obtained for Experiment 2.

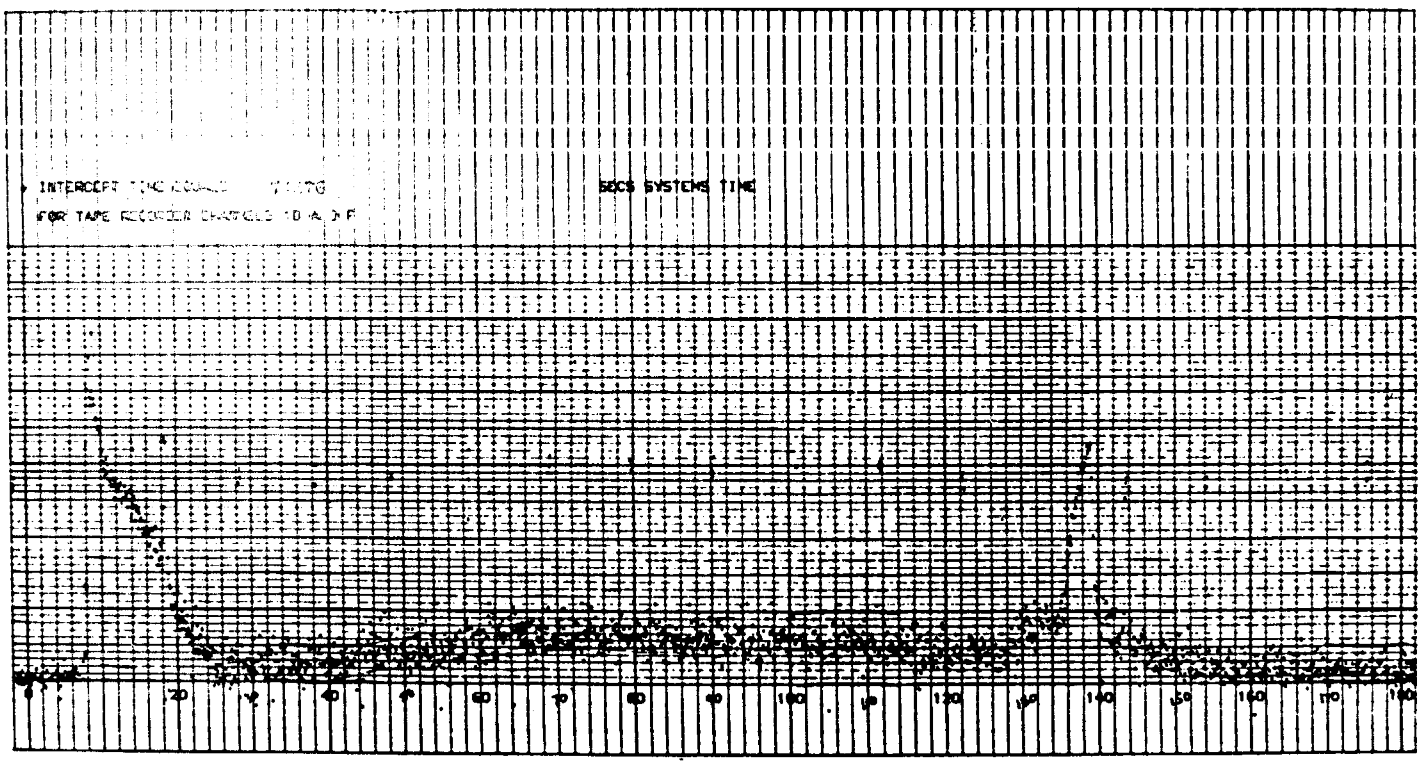

Fig. 15a. Tape data for one complete orbit of the albedo radiometer for Experiment 2.

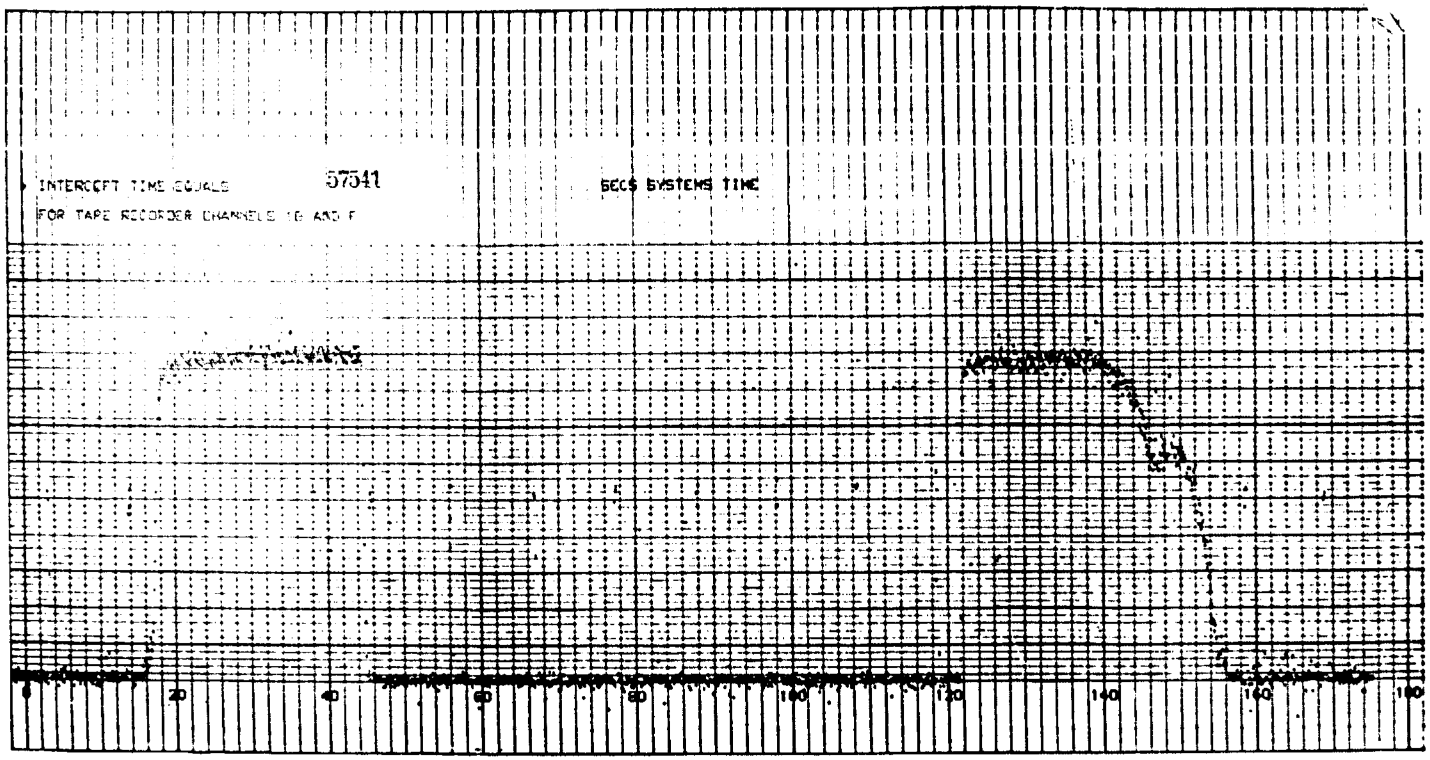

Fig. 15b. Tape data for one complete orbit of the solar radiometer for Experiment 2.

further problem, which was noticed in the second experiment, is that in the hard vacuum in space, filter characteristics may change. Nickel sulphate has water of hydration which evaporates in a vacuum leaving the crystal opaque in the ultraviolet, and, hence, the crystal must be hermetically sealed.

In these experiments, a very wide dynamic range was used because the magnitude of the radiance to be measured was unknown. This limited the precision to which measurements could be made. Now that the approximate radiance is known, subsequent flights can use a smaller dynamic range and linear amplifiers.

A third flight of this instrument is planned during the summer of 1963, using all information obtained in the first two flights to establish the dynamic range and magnitude. Both filters will be modified slightly, the vertical distribution filter to be more nearly monochromatic at the peak of the ozone absorption at 2550 Å and the background radiance filter to include the wavelength region up to 2900 Å. The latter change was made to obtain radiance data of possible use to a surveillance system.

APPENDIX A

Calculation of Effective Spectral Response

The absorption of radiation by ozone falls off rapidly as the wavelength of the radiation increases from 2500 to 3000 Å. Hence, the longer wavelengths of the solar radiation can penetrate more deeply into the atmosphere before being scattered back to the radiometer. The over-all spectral response of the radiometer thus depends upon the filtering of the ozone in addition to that of the radiometer itself. This effect of the atmosphere on the spectral response has been approximately determined by the following series of calculations. These apply to the albedo channels of the two experiments.

The product curve of the transmittance of the filter, the response of the photomultiplier, and the irradiance of the sun were calculated. For the irradiance of the sun, the data of Johnson [1954b] were used.

These products for the two radiometers are given by curves A, Figures A-1 and A-2.

The two-way transmittance of the atmosphere was calculated for normal incidence and viewing, down to depths of 70, 60, 50, 40, 30, and 20 km. For this calculation, the ozone absorption coefficients tabulated in the Handbook of Geophysics [1961] and the ozone concentrations of Johnson et al. [1952] were used. Each of these curves was then multiplied by pressure at that altitude [Handbook of Geophysics, 1961] divided by the fourth power of the wavelength (to weight by a quantity proportional to the corresponding Rayleigh scattering of the atmosphere). These curves also are plotted in Figures A-1 and A-2, except that the curves for deeper penetration which are too small to be plotted have been omitted. The sum of these curves, which represents the over-all spectral response, is plotted in Figures A-3 (left section) and A-4.

Under the above assumptions, the filter leak in the 3000 to 3400 Å region in the first radiometer does not make an appreciable contribution to the over-all spectral response. However, it is possible for this leak to be significant if the reflectance (scattering) at lower altitudes is greatly enhanced, as might occur in the presence of high level clouds. In Step III perfect diffuse reflecting clouds at 20 km were assumed. Their reflectance was converted to dimensions corresponding to those used in Step II [Handbook of Geophysics, 1961] and then added to Figure A-3 (right-hand peak). Note that this peak encloses an area somewhat larger than the area under the left peak.

It is important to remember that these calculations are approximate. However, they do illustrate that clouds can show through the ozone in the first experiment. This may explain the coarse fluctuations observed. It is probable, however, that this leakage is not sufficient to explain all of the discrepancy between the radiance values measured by the two radiometers.

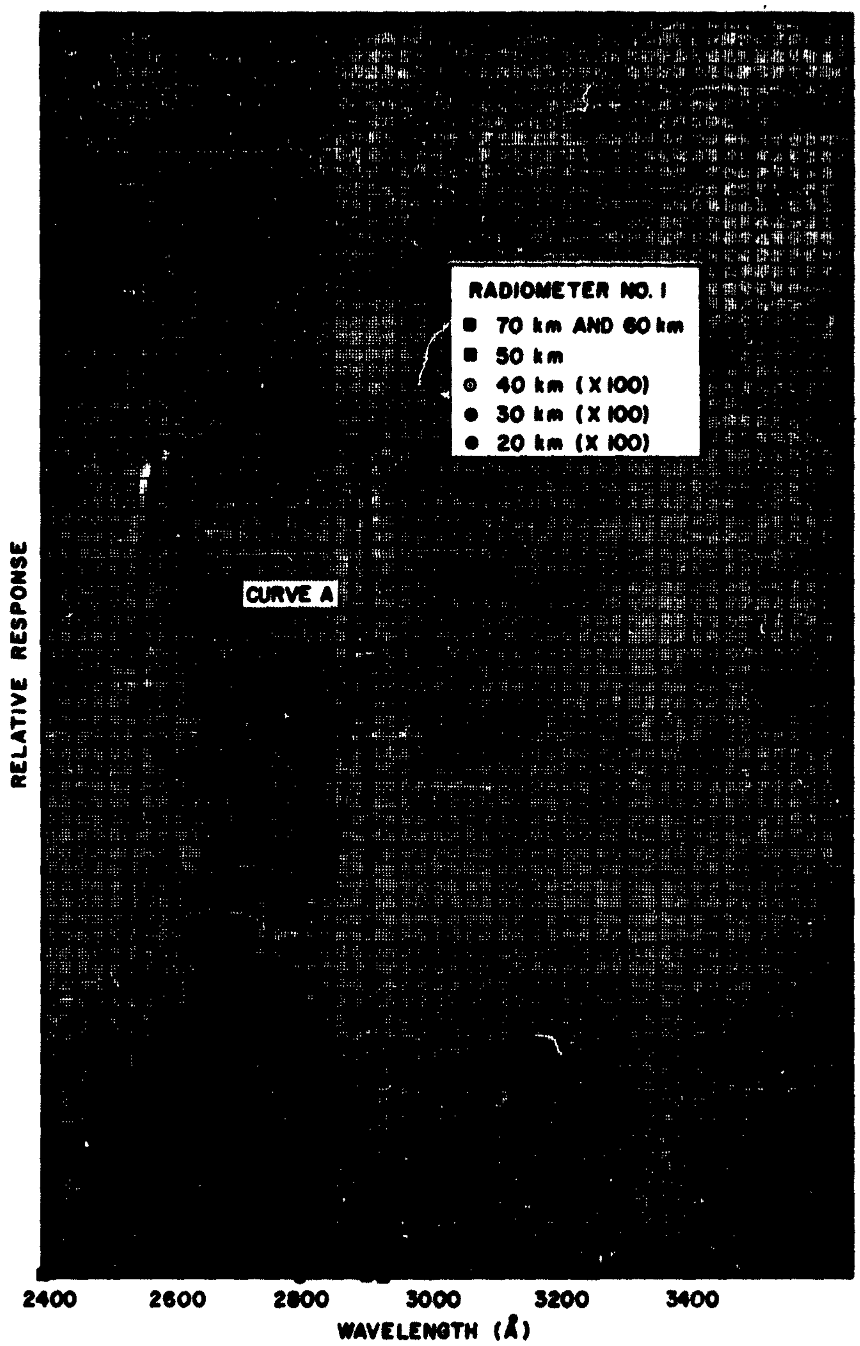

Fig. A-1. Calculated response for the albedo radiometer for Experiment 1.

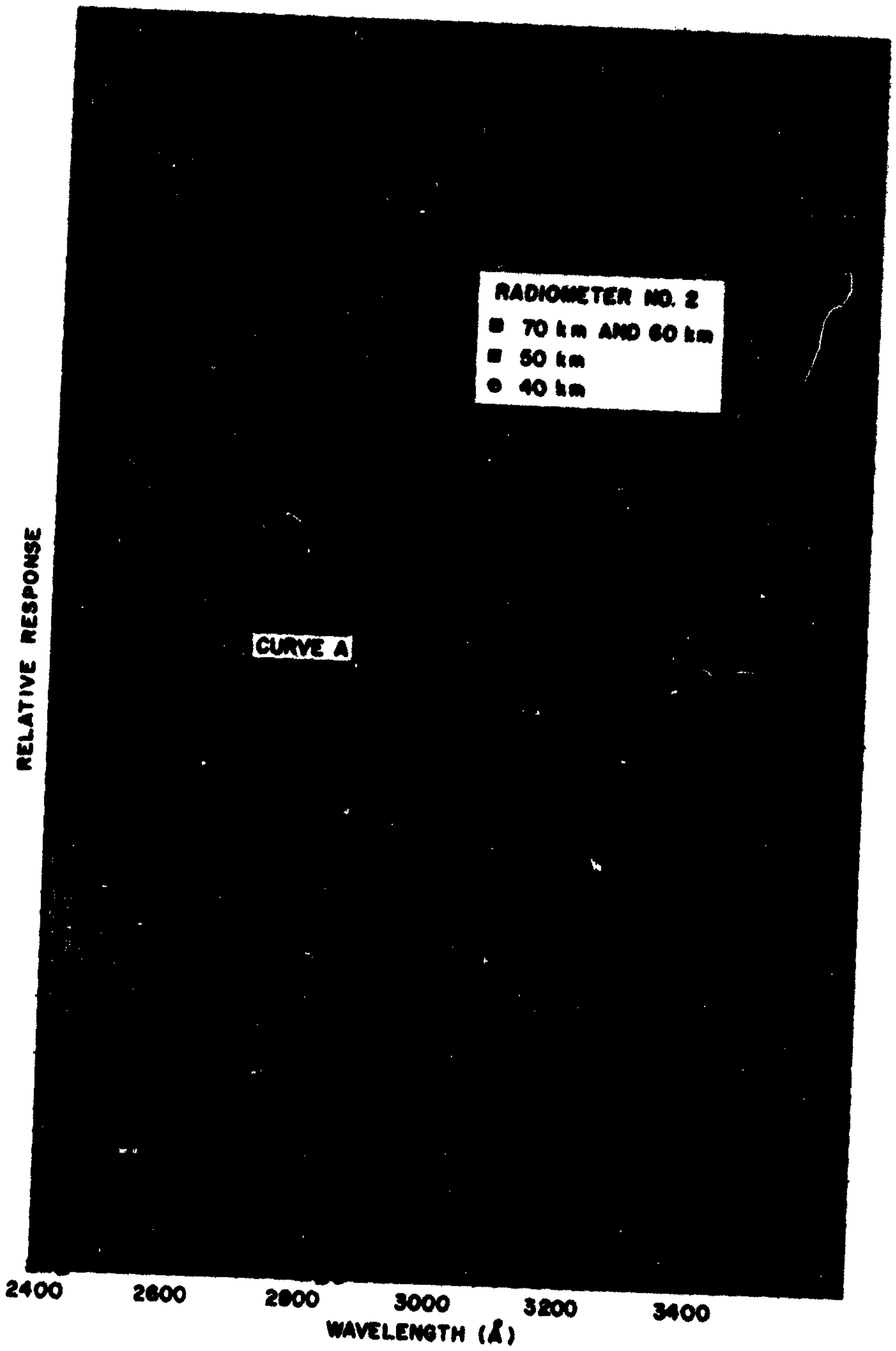

Fig. A-2. Calculated response for the albedo radiometer for Experiment 2.

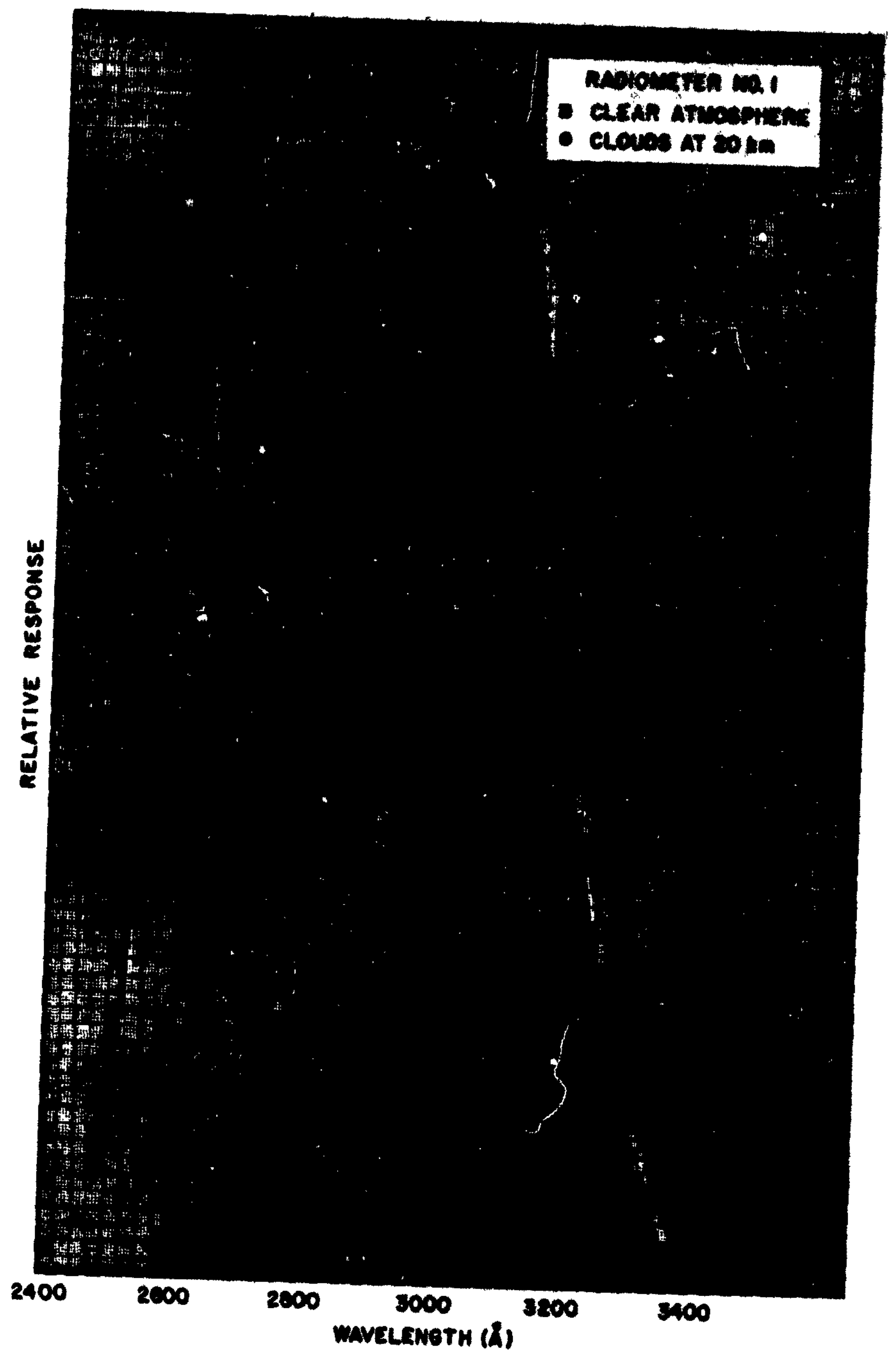

Fig. A-3. Calculated response for the albedo radiometer on Experiment 1 for clear and cloudy backgrounds.

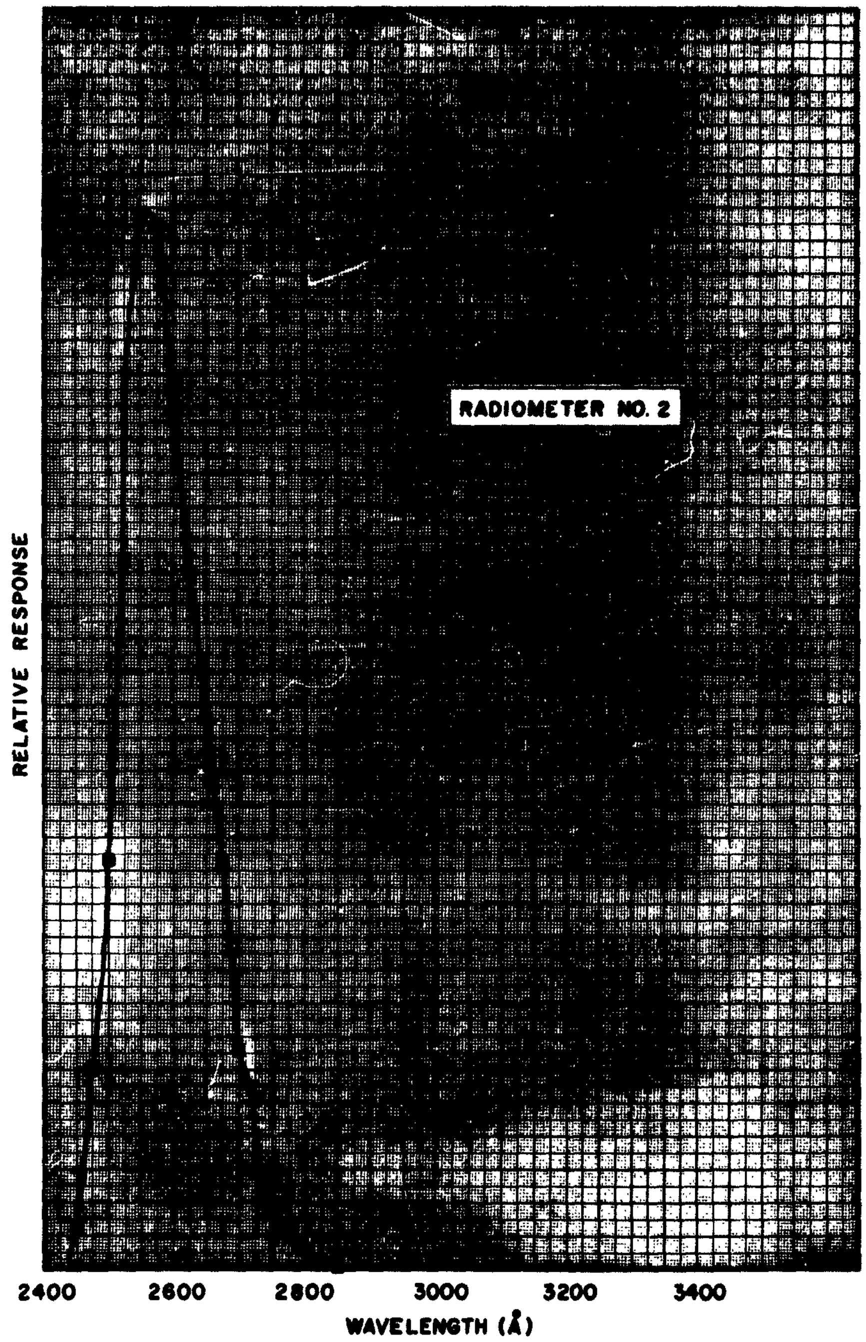

Fig. A-4. Calculated response for the albedo radiometer on Experiment 2 for clear and cloudy backgrounds.

APPENDIX B

Large-Angle Light Leakage

It was suspected that scattered light within the albedo channel of the radiometers contributed significantly to the background readings. To check this, an optical system was set up as nearly identical as possible to those flown. It was illuminated by a Mercury H-4 lamp through a collimator, and the angle of incidence was varied from 0^{o} to 45^{o}. The relative response as a function of angle of incidence is plotted on a semilog scale in Figure B-1. The readings at large angle are indeed small, but the associated solid angle is large. A numerical integration shows that the total response from 10^{o} to 45^{o} off axis is five percent of that within the on-axis field of view; hence, it does not cause a serious error.

There is also white light leakage around the edge of the filter. This is difficult to evaluate quantitatively. Its magnitude depends critically upon the exact fit of the filter in the filter holder. The photomultiplier response is down by two or three orders of magnitude in the visible. However, the spectral irradiance is up by more than one order of magnitude, the albedo is greater, and the wavelength interval also is larger. Hence, a small visible leak could be important, and it may explain the high radiance observed by the first radiometer.

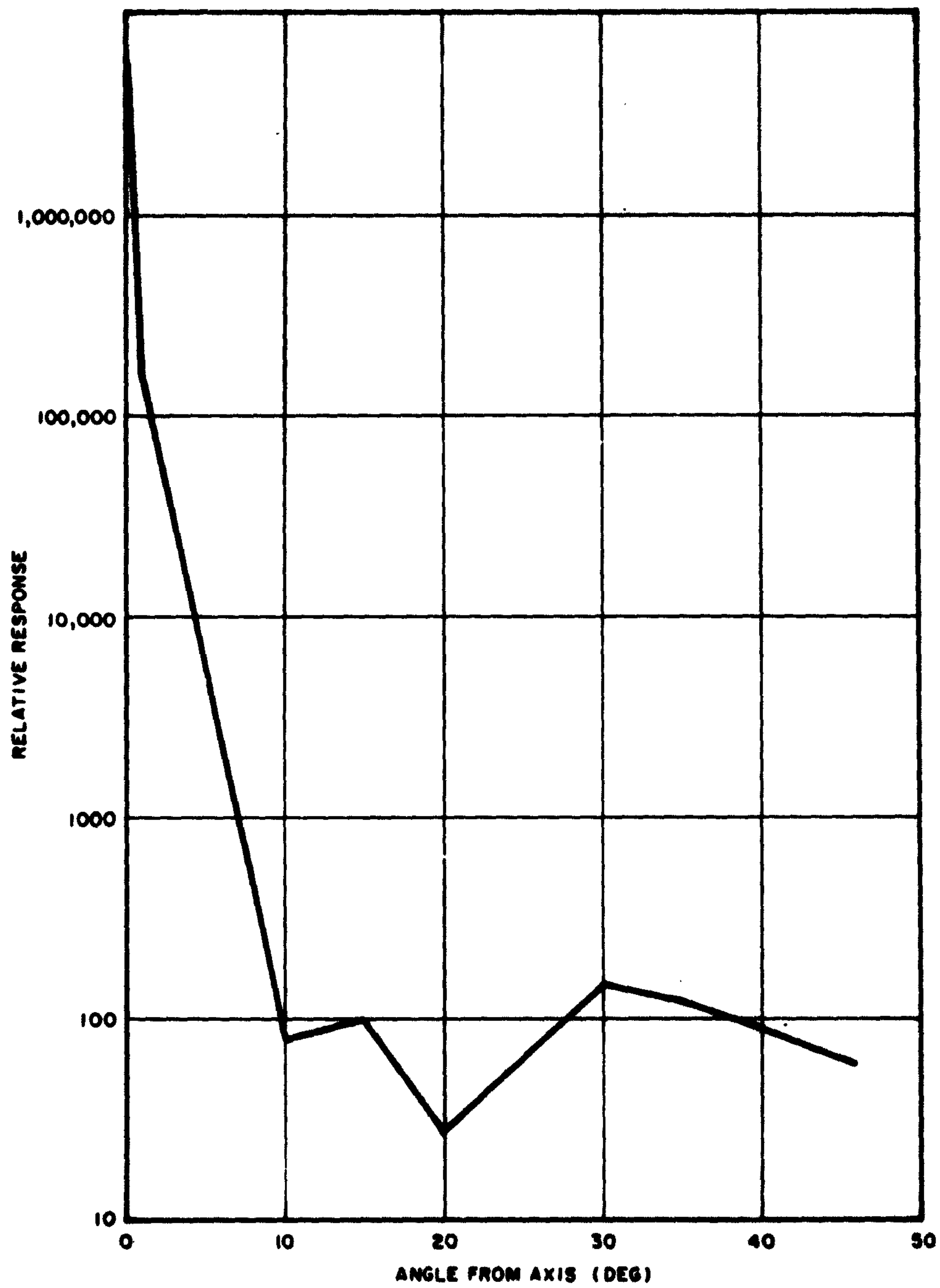

Fig. B-1. Angular response of the albedo radiometer for Experiment 1.

REFERENCES

Bates, D. R., and M. Nicolet, J. Geophys. Res., 55, 301, 1950.

Cabannes, J., and J. Dufay, Compt. Rend. Acad. Sci., Paris, 181, 302, 1925.

Craig, R. A., Meteorol. Monographs, 1, 2, 1950.

Fowler, A., and R. J. Strutt, Proc. Roy. Soc. (London), A93, 557, 1917.

Gotz, F. P. W., A. R. Meetham, and G. M. B. Dobson, Proc. Roy. Soc. (London), A145, 416, 1934.

Green, A. E. S., Space Science Laboratory, General Dynamics Corp., San Diego, Rept. ERR-AN-221, Oct., 1962. (To be published in Appl. Optics.)

Handbook of Geophysics, The Macmillan Co., New York, 1961, pp. 16-23.

Hennes, J. P., W. B. Fowler, and L. Dunkelman, Trans. Am. Geophys. Union, 43, 436, 1962.

Johnson, F. S., J. D. Purcell, and R. Tousey, J. Geophys. Res., 56, 583, 1951.

Johnson, F. S., J. D. Purcell, R. Tousey, and K. Watanabe, J. Geophys. Res., 57, 157, 1952.

Johnson, F. S., J. D. Purcell, and R. Tousey, Rocket Exploration of the Upper Atmosphere, edited by R. L. F. Boyd and M. J. Seaton, Pergamon Press, London, 1954a, pp. 189ff.

Johnson, F. S., J. Meteorol., 11, 431, 1954b.

Johnson, F. S., Satellite Environment Handbook, Stanford University Press, Stanford, 1961, Chap. 4.

Karandikor, R. V., and K. R. Ramonathan, Proc. Indian Acad. Sci., A29, 330, 1949.

REFERENCES (continued)

Paetzold, H. K., J. Atmospheric Terrest. Phys., 7, 128, 1955.

Regener, E., and V. H. Regener, Physik. Z., 35, 778, 1934.

Van Allen, J. A., and J. J. Hopfield, Mem. Soc. Roy. Sci. Liege, 12, 179, 1952.

Venkateswaran, S. V., J. G. Moore, and A. J. Krueger, J. Geophys. Res., 66, 1751, 1961.

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Aerospace Corporation, El Segundo, California. EXPERIMENT AND PRELIMINARY RESULTS OF SATELLITE DETERMINATIONS OF THE VERTICAL DISTRIBUTION OF OZONE AND OF THE ALBEDO IN THE NEAR ULTRAVIOLET, prepared by E. B. Mayfield, R. D. Rawcliffe, R. M. Friedman, and G. E. Meloy. 3 May 1963. [46]p. incl. illus. (Report TDR-169(3260-50)TN-2; SSD-TDR-63-103) (Contract AF 04(695)-169) Unclassified report This report describes a satellite experiment to determine both the vertical distribution of ozone above 70 km and the radiance of the atmosphere at the center of the Hartley absorption band of ozone at 2550 Å. Two flights of the experiment have been made successfully, resulting in measurement of the vertical distribution between 60 and 85 km and of the radiance at the nadir for sun angles from 90° to about 49°. The vertical distribution data agree with previous results below 70 km and (over)	UNCLASSIFIED UNCLASSIFIED

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